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Mobile and Netted Air Defence Systems

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Summary: This paper describes a sensor- and weapon independent co-ordination and communication concept for use in coming generations of mobile SHORAD and medium range air defence systems. Actually, the proposed concept will handle most known weapon systems. The presented system generates and maintains a ratified total air picture from available track information, whether from system specific radar sensors or from system external sensors via data links. Airspace Control Means, and their effect on Threat Evaluation and Weapon Allocation operations, are totally integrated in the system, allowing full and safe use of friendly aircraft during air defence operations. Powerful training- and simulation software allow fully synchronised system training sessions from classroom equipment or from any operator position in the system.

System Architecture: Most air defence systems comprise sensor(s) and weapon co-ordinated by a C2 element via some form of inter-communication medium. Communication with other air defence assets (lateral) and higher command usually happens via dedicated point-point data links, using formats and protocols defined in National, NATO, or US standards.

The air defence system concept described in this paper mainly utilise international communication standards (ISO) and Wide Area Network (WAN) connectivity, which reduces system vulnerability towards errors and single point failures.

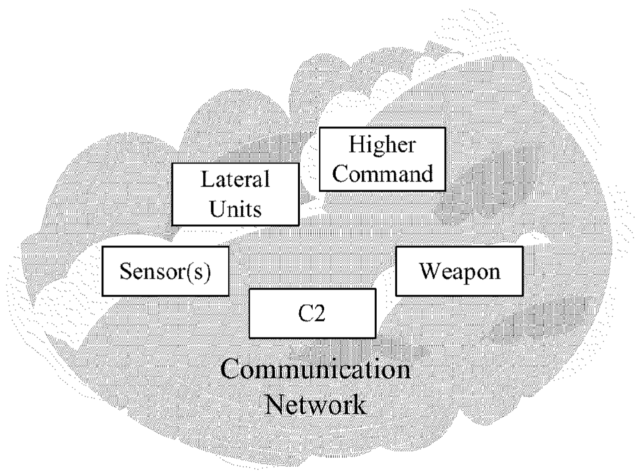

Fig. 1 Air Defence System

Traditionally, an air defence unit comprises sensor, weapon and C2 interconnected by cables, functioning as a stand-alone weapon units. If any part of such a unit becomes unserviceable or damaged, the whole weapon

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unit is out of operation. It is possible to interconnect several such stand-alone weapon units to introduce redundancy, but this introduces additional mandatory requirements:

- air picture synchronisation (fusion)
- real-time communication
- secure communication
- co-ordination of firing between systems
- synchronised training and simulation

The concept proposed in this paper overcome the mentioned obstacles and provides inherent element redundancy. The concept is based on solid experience from air defence system implementations in Denmark and elsewhere.

Concept: The proposed concept deals with 5 main design requirements:

- communication
- common air picture
- sensor co-ordination
- weapon co-ordination, control and maintenance
- training and simulation

Communication

The most essential part of the proposed system is communication. In order to stay mobile, the communication system must support wire-less operation and provide as much bandwidth as possible. During crisis or war the wire-less environment is noisy and most likely contaminated by intentional jamming. This mandates some essential requirements to the chosen communication system:

- error correction
- frequency agility
- line-of sight
- directional antennas

It is our experience that an area system based on mobile communication nodes using frequency agile radios, with forward error correction, is a good choice. Nodes should be equipped with directional antennas and should support down-the-hill connections to a number of system elements by cable or by radio. The nodes must be interconnected in a meshed network, covering the entire area of interest.

Communication stacks should include TCP/IP protocols and standards well known from the Internet. A lot of standard software is available covering every aspect of network communication and system management.

Common air picture

Every sensor in the system, whether active or passive, should be connected to a node in the communication network. The sensors must be equipped with sufficient processing capabilities to maintain 2 track tables, a local table and a copy of the track table in the network.

For each processing cycle, individual sensors compare their local track tables with the network table and decide, from a quality comparison, whether any of the local tracks are missing, or have a higher quality figure, than in the network table. If yes, then each sensor will broadcast such tracks. This ensures the air picture in the network is fused, current and of the highest quality possible, while still conserving bandwidth.

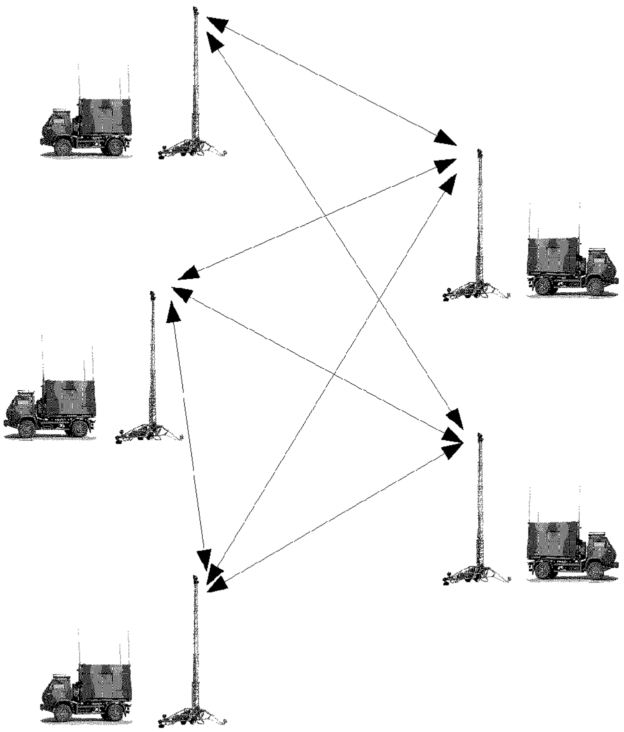

Fig. 2 Meshed communication network example

The quality figure is naturally an essential parameter and should comprise all available track information in as near real-time as possible.

Tracks in the common air picture should be identified, if at all possible. Most active sensors are equipped with IFF equipment, and can contribute to the identification process. This is normally not sufficient to give sure identification of a track, as IFF equipment can fail, remain switched off or be loaded with the wrong identification codes. Additional identification is required, and can be provided, by the co-ordination elements in the system, from available Airspace Control Means (ACM).

A common identified air picture is a requirement in any air defence system, but it needs sensor co-ordination and subscribers before it's potential can be exploited.

Co-ordination

It is desirable to keep the number of personnel in a given operation to a minimum. It is therefore obvious to control participating sensors remotely and leave the sensors unmanned. A number of sensor control facilities could be placed anywhere, hooking up to the network via one of the access nodes in the system. One control element would suffice, but for redundancy- and continuity reason at least two such elements would be required per system.

Operators in the Co-ordination element would maintain the ratified air picture and operate the sensors according to daily orders, e.g. frequency selections, IFF codes, antenna rotation speeds, blinking, identification, etc.

A netted and ratified air picture is now established, ready for use by subscribers within communication coverage of an access node. In an air defence system subscribers would typically be air defence co-ordination and control facilities and associated weapons.

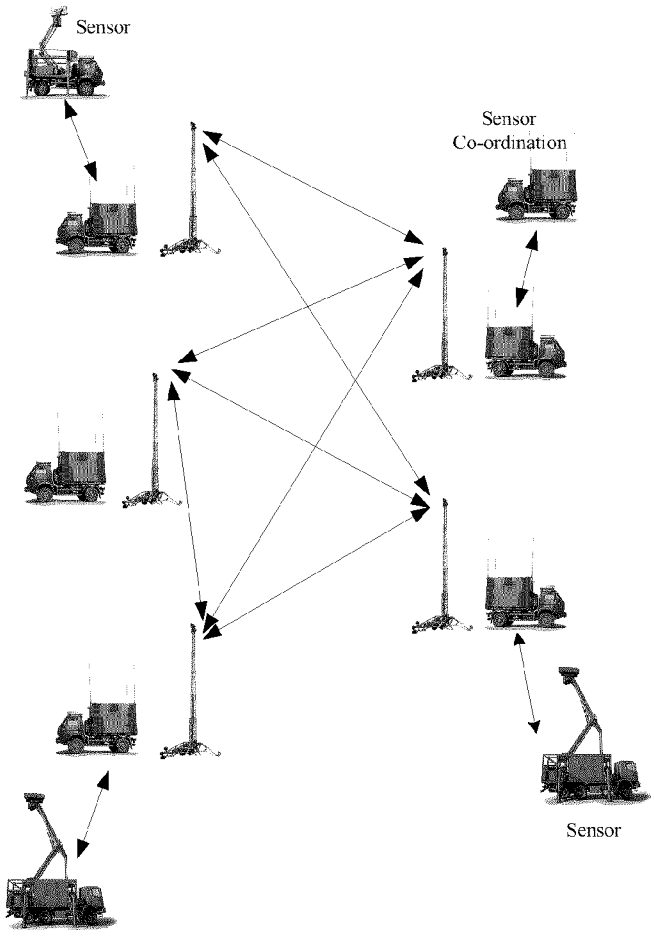

Fig. 3 Network with sensors and co-ordination

Weapon co-ordination, control and maintenance

Much in the same way as with the sensors in the system, it is possible to remotely control and co-ordinate a large number of air defence weapons from a central co-ordination and control element.

The air defence weapon in question will interface to a communication access node, anywhere in the system, and report its position and address to the central co-ordination and control element. If several weapons access the same node, some type of radio sub-net is established using TDMA- or wireless Ethernet protocols, compatible with the number of weapons in the sub-net and with the required reaction time. One example could be a cluster of V-SHORAD weapons, within radio coverage of a given access node, using VHF radios for communication.

Another example could be medium range SAM, e.g. HAWK, with it's own dedicated fire control element, interfacing to the nearest access node by radio or fibre-optic cable. A typical HAWK set-up would comprise 3 launcher, each with 3 HAWK missiles, and 1 illuminator radar, interfacing to the fire control element by fibre-optic cable

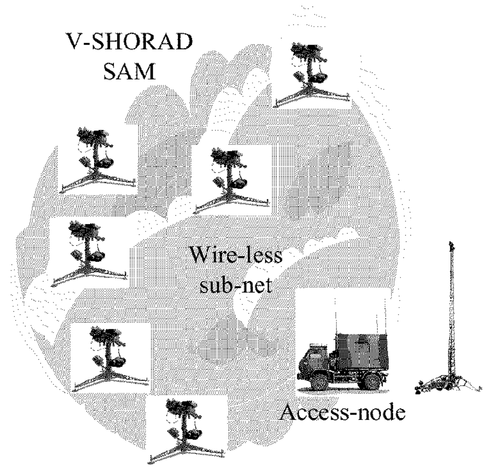

Fig. 4 V-SHORAD wireless sub-net

Figure 5 below shows a typical set up at an access node with Enhanced HAWK as the main air defence weapon and V-SHORAD for close-in air defence. Fibre-optic cable is preferred over VHF radio communication as the access medium mainly for bandwidth and security reasons. The fire control element with the Enhanced HAWK weapon should be designed to operate equally well as a dedicated fire control element with weapons attached or as a main fire direction element for the entire air defence system. Just one main fire direction element could co-ordinate firing within the total air defence system, using Threat Evaluation and Weapon Allocation algorithms tailored to accommodate the range of weapons employed in the system. Suitable TEWA algorithms, for this type of air defence system, are found elsewhere in these proceedings.

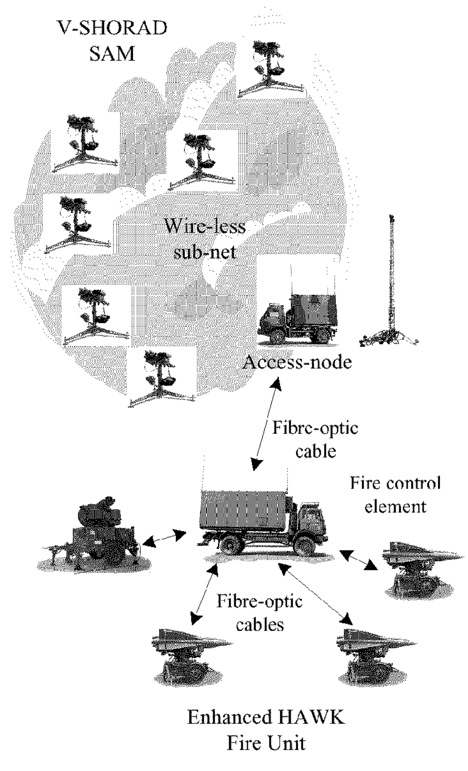

Fig. 5 V-SHORAD and HAWK access

Using identical fire direction and fire control elements in the system, ensures a high degree of redundancy during operation, i.e. any fire control element could assume the role as central fire direction element if damage has occurred or during movements.

A very essential part of weapon co-ordination and control is distribution of common Airspace Control Means (ACM) throughout the system. ACMs define all aspects of airspace control in the total area of interest. ACMs are used by the central fire direction element to allow safe transition of friendly aircraft in the area while at the same time being able to utilise associated weapons to their maximum potential. ACMs also serve with additional information in the air picture identification process, by allowing procedural identification of own aircraft in the area.

During operation all actions, and the result of these actions, may be recorded for post operation analysis, or for use in training scenarios.

A mobile air defence system has now been defined, establishing and maintaining a ratified total air picture for use by a variation of air defence weapons. Fire direction and co-ordination elements have been introduced, able to address the weapon in the system which is best placed to deal with a given threat. The use of common ACMs throughout the system ensures maximum protection of own aircraft from own fire while at the same time utilising associated weapon to their maximum potential.

Two final and important aspects of co-ordinated air defence is the ability to communicate with air defence assets of neighbouring forces (lateral communication) and to receive orders and transmit status to higher command. This is traditionally done via dedicated gateways, and, dependent upon the standard used for communication, the flow of information can be one-way, two-way, tactical information only or everything of interest. Much used standards are Link-11B and ATDL-1 for point-to-point tactical communication, LLAPI for point-to-point exchange of both tactical and strategic information and Link-11 or Link-16 for tri-service network operations. In addition to these standards, which only deal with the exchange of data communication, other standards define gateways for the exchange of voice.

Gateways are usually located within access nodes of the system, and may be addressed and used by all elements of the system. Only one gateway per system is used at a time to another system, meaning that only one access node will be active as gateway. Which one, does system management at all times define.

It is now possible to show an entire mobile and netted air defence system with all it's interfaces:

Maintenance

It is quite normal to allocate a mobile maintenance facility to a mobile air defence system. The maintenance facility will typically store spare parts to intermediate level and be able to repair sub-assemblies to printed circuit card level (exchange of printed circuit cards).

In a netted system as discussed here provides some interesting possibilities for on-line and remote maintenance. The maintenance facility can connect to an access node, and via the network access all elements of the system. If all elements are foreseen with diagnostic tools, and the software to invoke these tools, e.g. SNMP (Small Network Management Protocol), it will be possible to monitor, on-line, the inside of all computers, routers and switches in the network from the remote maintenance facility. It is therefore possible to receive immediate warning if a problem is developing, and to pinpoint the location and nature of the problem. This will improve the faultfinding process and greatly reduce the time to repair. It is even possible to remotely re-route connections in a router, if congestion occurs or if a port on the router is damaged.

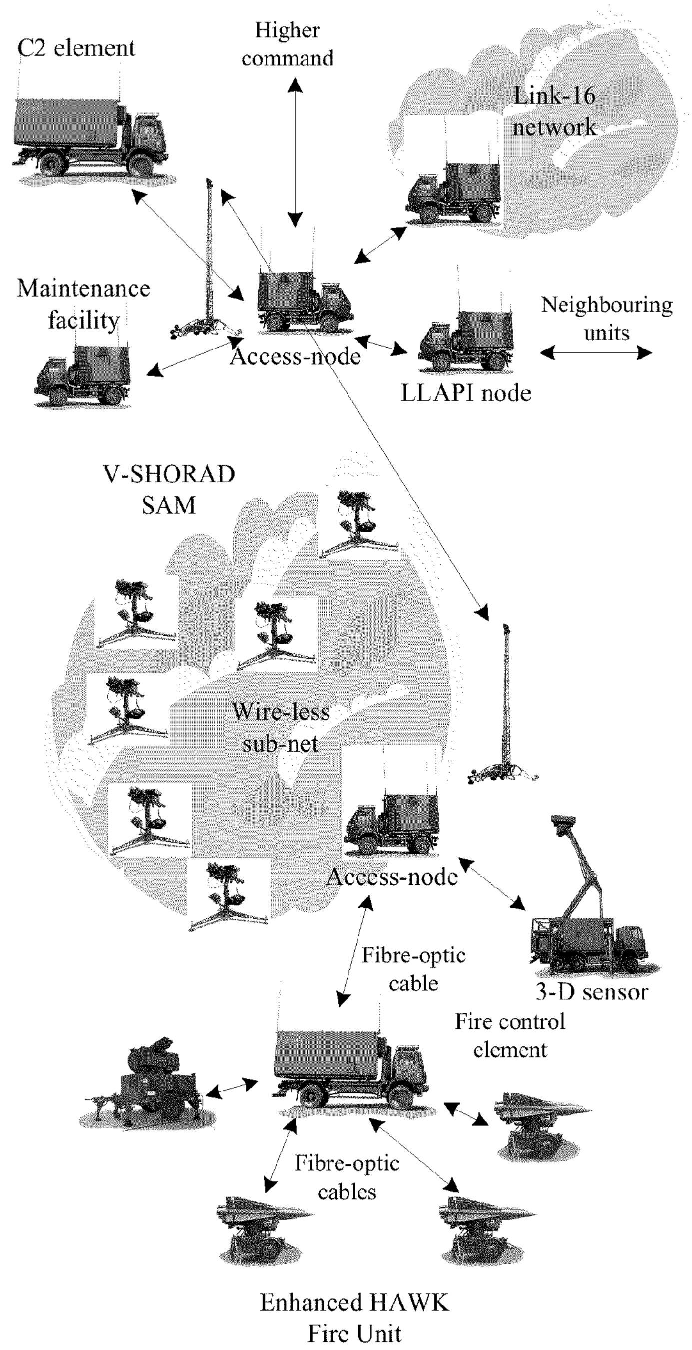

Fig. 6 Total air defence system

Training and simulation

In a netted system as suggested above, training of operators can take place anywhere in the system. A common training scenario will run on one of the workstations in the system, ensuring a completely synchronised execution throughout the system. It is also possible to train operators at positions in parts of the system by simulating the parts not participating. It is even possible to train operators in a classroom set-up, simulation elements of the entire system including external data links.

A given training scenario may be constructed at an operator position in the system, or at a classroom workstation. It is possible to use recorded live scenarios and edit these for use as a common training scenario. This ensures known and realistic scenarios, which may be used for elementary, as well as advanced, training of any type of operator in the system.

Actual implementations: A mobile and netted air defence system, like the one described in this paper was designed by TERMA Elektronik AS. The system is now being delivered to the Danish Airforce under the acronym Danish Enhanced HAWK (DEHAWK). The system under delivery comprises 3-D radar sensors, STINGER missiles on lightweight tripods and enhanced HAWK missile sub-systems.

Great emphasis was put into the design of a sensor and weapon independent system, supporting virtually any type of radar sensor and virtually any type of air defence weapon. TERMA developed the Operation Centre (OC) which may serve as central fire direction element, without weapon, and/or as fire control element with a flexible weapon interface capability. When the HAWK missile is phased out, a new missile is quite easily interfaced. A powerful Weapon Engagement Controller (WEC) was also developed to serve as fire control element for manpad missiles or AAA guns in wireless sub-networks.

The area communication system, including access nodes and communication equipment, was delivered by the Danish Airforce as government furnished equipment (GFE).

Some DEHAWK key figures:
Area communication system: 2 Mb trunks, C-band.
Radar sensors: 3-D, C-band, 100 Km range.
M-SAM: Enhanced HAWK with fibre-optic cable interfaces to the OC. Cable lengths: up to 1 km.
V-SHORAD: STINGER with Weapon Engagement Controller. Up to 12 Fire Units per sub-net.